The Canadian Entomologist

Vol. LXXXII January 1950 No. 1

Distribution of Progeny by *Cryptus inornatus* Pratt (Hymenoptera: Ichneumonidae)

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(CONTINUED FROM LAST ISSUE)

The Effect of Previous Parasitism

The results obtained in the experiments just described indicate that the discriminative ability of the female parasite operates to enable the parasite to distinguish between hosts which have been parasitized previously, not only by itself but by other members of the species, and perfectly healthy hosts. If this were not the case, series in which the densities of the female parasite populations were high would have given results which were more nearly approximate to a random distribution of progeny among the available hosts. As we have seen, the tendency was for the parasite to avoid superparasitism under all conditions, i.e., to exercise a deliberate choice of hosts.

No special test was made of the effect of previous parasitism on the way in which the eggs were distributed. It is possible, however, to show that females are capable of recognizing previously used hosts as unsuitable media for the reception of their progeny. The data in Table I gives a comparison which may be used for this purpose. Thus, the distribution of eggs over a period of 48 hours did not differ significantly from that observed during 24 hours in its efficiency, although during the second 24-hour period an appreciable proportion of the available host population had already been attacked and used for oviposition and there was therefore a certain number of parasitized hosts present in the area. Further egg-laying which took place during this second period was clearly provided for by a further search for new hosts and the finding and use of approximately an equivalent number of these new hosts for the additional progeny. The number of parasite eggs found on each host individual was the same in each series and the efficiency in distribution therefore did not differ significantly as a result of the presence in the host population of previously-parasitized individuals.

Taken in conjunction with the somewhat similar but less clear-cut results in the varying parasite density series, the evidence is sufficient to warrant the conclusion that *Cryptus* is able to distinguish between healthy and parasitized host individuals very readily. This conforms with what is known of other entomophagous Hymenoptera studied. The occurrence of a high degree of superparasitism at the low host densities does not necessarily mean that a breakdown in the faculty takes place. It implies, rather, that when host material is scarce the physiological urge for depositing mature eggs is overwhelmingly predominant and forces the female to utilize hosts which are available whether they are parasitized or not, although under more favourable circumstances she would normally avoid doing so as far as the former are concerned.

The Effect of Varying Area

In the present case, it was desired to observe the effect on the efficiency of the parasite which is produced by varying the area over which the search for hosts takes place while, at the same time, keeping the absolute numbers of

parasites and hosts constant. By doing this, the host/parasite ratio was constant as an absolute factor but the population of each insect per unit of area became varied according to the different units of area adopted. The object of this procedure was to ascertain, as far as possible, whether any extra effort on the part of the searching parasite was observable when the available host population was dispersed over a wider area and was therefore more diffuse and difficult to find.

Two widely different areas were tested, the larger being approximately 15 times greater than the smaller. These were obtained by using cages of different dimensions and placing the same number of parasites and hosts in each. The hosts were in all cases scattered at random over the floor of the cage. Females were all of the same age and had been mated and fed prior to use. The exposure time was 24 hours and there were six replications of the comparison.

TABLE V.

Cryptus inornatus: EFFECT OF VARYING AREA WHEN THE ABSOLUTE NUMBERS OF HOSTS AND PARASITES REMAIN CONSTANT.

	SERIES		
	A	B	C*
Area in square inches	8.1	119	8.1
Host density per square inch	1.25	0.08	0.5
Hosts per female: attacked	5.5	5.4	2.4
used	2.8	2.2	1.6
=percent of available	28.0	22.0	16.0
Eggs: number per female	4.0	3.6	3.5
per host attacked	0.7	0.7	1.5
per host used	1.5	1.6	2.2
Hosts in modal group percent	35.0	26.0	26.0

*Series C is obtained by interpolation from results of previous single female series with varying host density per unit area (*vide* Table II and curves). It is taken at the point where the percentage of hosts falling into the modal group is equivalent to that in Series B.

The details and results are given in Table V. Each cage had 2 parasite females and 10 hosts but the data are stated as results per female. Comparing the two experimental series, A and B, it will be noted that:

(1) approximately the same number of hosts were attacked in each case;
(2) only slightly less hosts are used in the larger area;
(3) approximately the same number of eggs are laid;
(4) the ratio of eggs to attacked hosts is the same in each case;
(5) the number of eggs per host used is approximately the same;
(6) the percentage of hosts falling into the modal group of the frequency distribution of eggs among hosts attacked is appreciably lower when the area is greater. The modal group is as found in the earlier experiments.

For the purpose of further comparison, series C is added. The figures here are derived by interpolation from the curves obtained in the experiments with single females at different host densities per unit area and are taken at the point where 26 percent of attacked hosts fall within the modal group of the frequency distribution (i.e., where only one egg occurred on each host). At this point there were 4 hosts in the smaller type of cage as compared with 10 hosts in series A

and B. In series C, less hosts are attacked (approximately half as many) and less are used than in the two other series. On the other hand, as might be expected, as many eggs were laid during the period. The percentage efficiency in series C was 46 percent.

Compared with series C, series B shows a decided superiority in the number of hosts attacked and in the utilization of hosts. It exhibits a higher degree of efficiency (61 percent) in distribution, although it is equivalent in respect of the percentage of hosts falling in the modal group. These results are undoubtedly largely influenced by the higher absolute number of hosts in series B.

In comparison with series A, where the absolute number of hosts is the same, series B closely approximates to the results obtained in the former, although the efficiency with which the parasite progeny are distributed is lower. It can therefore be concluded that, when the same number of host individuals is dispersed over a wider area, i.e., when the number of hosts per unit of area is decreased, the female parasite is able to exert a greater effort to cover the increased area and to find the requisite number of hosts to satisfy her needs during the time which is allowed.

Although she is thus able to locate and attack as many hosts during this period, however, the efficiency with which these hosts are used, or with which her eggs are distributed among them, is impaired to some extent so that the percentage of the host population bearing only one parasite egg per individual is lower than in a more concentrated host population. It is then more comparable with a situation in which there are fewer actual hosts available. The relevant limiting factor here is no doubt the time taken to search the area for hosts.

Once again it is evident that the phenomena observed are very largely influenced by the physiological factor and by the absolute number of hosts available within the universe, irrespective of the size of the latter. So far as these observations go, these factors would appear to be of greater import than the factor of host/parasite ratio, although the latter obviously becomes concerned when the number of hosts falls below that required for the daily oviposition needs of the parasite population.

Unfortunately it was not possible at this time to carry the above comparison to its logical conclusion experimentally, i.e., to the point at which the increased area would reach the maximum possible size which could be covered by the female parasite during the given period of time. Such an area would no doubt be considerably larger than the larger one used here. There is no doubt, however, that such a procedure would result in a progressive decline in the number of hosts found and used per unit of time as the area became greater and in a gradually decreasing efficiency in egg production.

Such an extension of the observations would prove interesting from an academical standpoint but would bear little relation to the facts of Nature since host populations, where they do occur in the field, are normally concentrated within a comparatively restricted area at the bases of their food-plants. The parasite which locates one of these populations will therefore be supplied immediately with an adequate number of hosts for its total egg production without the need for further search of the general environment and it will not be required to traverse a very great area in the immediate environment in order to find hosts. Under normal field conditions, therefore, we should expect to find that the efficiency of the parasite in controlling the host will not vary appreciably from place to place in a given area, provided other conditions are favourable, and this will be so independently of the distribution of the host population if sufficient numbers of the latter are present.

The Host/Parasite Ratio

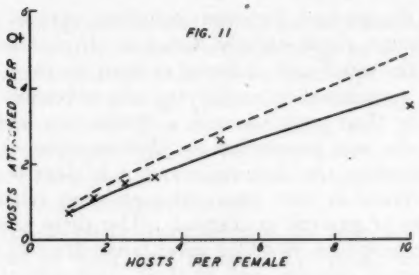
In the tests made with single females at different host densities, a definite correlation was found between the number of hosts available per female and the number attacked, the number of effective eggs per female and the percentage of the eggs which was effective. The ratio of hosts to parasites was therefore shown to be an important factor in the modification of the efficiency with which the parasite progeny were distributed. In the series wherein the parasite density was varied and the host population kept constant there was, as already pointed out, a progressive change in the host/parasite ratio as the population of the parasites was increased. Since this variable was of importance in the former experiments, it may be presumed to have some influence in the latter. Hence, where the parasite density was varied, we have two significant variables which influence the host/parasite relationship and which act simultaneously to modify the final manifestation of the discriminative faculty of the parasite female. It is necessary to distinguish between these two and to attempt to assess their relative values in the phenomena observed.

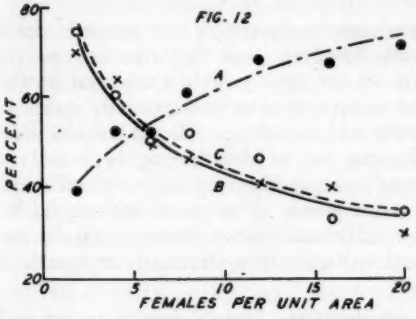
For this purpose, the data for the varying parasite density series have been recast in order to relate the various points to the number of hosts available per female in each of the different population densities chosen. These have been plotted and a comparison made in each case where possible with the results obtained in the single female series. The effect of this ratio of hosts to parasites on the number of hosts attacked is shown by curve B in figure 11. The general trend is very similar to that shown by the comparable data for single females (curve A), namely, an increase in the number of hosts attacked per female with an increasing host/parasite ratio.

Numerically the results are very close in the two series. The general importance of this factor in defining the efficiency of the parasite population in the finding and destruction of hosts is therefore demonstrated. It is evident that the diminishing ratio of hosts to parasites which results from increasing the parasite population in an area in which the host population remains constant leads to a decreased efficiency of the individual parasites even though the total destruction of hosts by the whole parasite population is increased. The decrease is a progressive one whereby the increments in mortality from parasite attack become successively smaller with each increment in the parasite population.

This is brought out clearly by the curve showing the percentage of the host population which is destroyed by the different series of parasite concentrations (fig. 12,C). Here it is clear that doubling the number of individuals in the parasite population, for example, does not produce a comparable effect and double the number of hosts attacked. At a density of 20 female parasites per unit area, 74 percent of the hosts present were attacked; but at a density of 40 females per unit area, assuming that the curve used still holds good at that point, only 88.4 percent of the hosts would be attacked. The combined effect of an adverse ratio of hosts to parasites and overcrowding of the parasite population therefore has the effect of considerably reducing the effectiveness of the parasite in the control of the host.

A similar phenomenon is observed in the case of the percentage of eggs which are effective as related to the number of hosts per female parasite. Curve A of figure 13 shows the results of this plotting for the series with varying parasite density. This may be compared with the single female series (Curve B) for the same host densities per female. The two sets of data are very similar, again indicating that the host/parasite ratio remains an important factor modifying the efficiency of the female parasite in the distribution of her eggs.





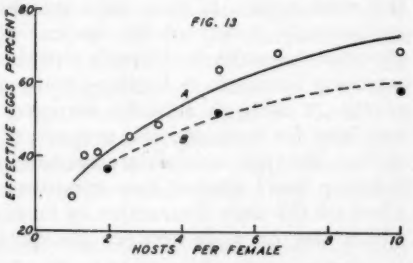


FIG. 11. *Cryptus inornatus*: Hosts attacked per female as related to the hosts available per female; continuous line=females under different parasite concentrations; broken line=results with single females per unit area.

FIG. 12. *Cryptus inornatus*: Effect of varied parasite density on A, hosts parasitized; B, effective eggs per female; C, hosts falling in the modal group.

FIG. 13. *Cryptus inornatus*: Comparison of effect of host density on effective eggs per female in A, series with varied parasite density and B, single females per unit area.

Varying the parasite density does not have any effect whatsoever upon the total number of eggs produced per female during the 24-hour period. The number was approximately constant throughout the series, no significant difference being observed between the means at the different density points. This is in sharp contrast with the results obtained in the earlier work with *Chelonus*, where increasing numbers of parasites per unit area gave an increasing divergence from the data obtained with single females. There is therefore no evidence of a direct effect of parasite density, as such, in the case of *Cryptus*. This is linked to the physiological peculiarity of the reproductive system.

Discussion

From the immediate practical point of view, the foregoing data were of use in regulating the large-scale rearing of *Cryptus* in the laboratory so that material could be obtained for shipments in the most economical way. By arranging the relative populations of host and parasite per unit area according to the optima indicated by the experiments, the incidence of superparasitism was reduced to a minimum and it became unnecessary to adjust the distribution of eggs on the hosts. This reduced the labour involved very considerably. The total daily production of the *Cryptus* adults then became limited mainly by the low individual reproductive potential of the parasite and by considerations of space and labour available for the project.

If we make a comparison between the three species of parasites already studied from the present angle, namely, *Cryptus*, *Microbracon* and *Chelonus*, it is evident that certain significant differences exist in their relationships to the variables which are concerned in modifying the efficiency of their respective females in maintaining their populations at a satisfactory level. Their respective values in destroying the host population are likewise affected. At the same time, certain essential similarities are observable and it is clear that some of the same factors are of importance in each case, although their relative significance may vary with the species of parasite concerned. The three species, in fact, form a fairly well-graded series which affords a good range illustrative of the oviposition habits of hymenopterous parasites and of their relationships to the effectiveness of the parasites in the limitation of the populations of their hosts.

In the following discussion the reproductive activities of the parasites form the main topic. It must be remembered, however, that they do not go on continuously in any of the species. Part of the time which is allowed in the experimental series is obviously not so taken up but some is necessarily spent in searching for food, in feeding by the adults and in resting. A proportion only of the 24 hours is actually occupied by the act of distributing eggs and in searching for hosts and this proportion may conceivably vary with the different species, although no data are available on this point. The possibility should be borne in mind since it may constitute an additional factor having a significant effect on the daily destruction of hosts and will therefore affect any comparison which may be made between the species.

Before proceeding to deal with the details of the various factors concerned in the prosecution and the modification of the act of distributing eggs by the female parasites, we may briefly compare the habits of *Cryptus* with those of *Chelonus* and *Microbracon* in order to draw attention to the fundamental similarities and differences which must have a direct bearing upon their respective behaviour and efficiency. These peculiarities, it will be observed, are not solely, or even mainly, concerned with the host/parasite ratio but are also psychological and physiological in origin.

In the case of *Chelonus* we have a parasite which is characterized by its extreme dependence upon a favourable ratio of hosts to parasites in order to attain to its greatest efficiency. The females are very prolific and the production of eggs is more or less continuous throughout the reproductive life of the female. Oviposition therefore proceeds more or less uninterruptedly as long as host material is available within the universe inhabited by the parasite. There are no periodical intervals at which ova mature and each host individual is ideally served with a single parasite egg. Efficiency in the distribution of eggs, however, is mainly dependent upon the number of hosts available for the use of each parasite female within the given area, i.e., it is almost entirely density-dependent in character. The density of the parasite population per unit area also influences this efficiency, both as it concerns the individual parasite and the whole population. This has been shown to be largely due to the deterioration in the host/parasite ratio with increasing parasite density and a constant host population (Ullyett, 1949).

Females of *Microbracon hebetor* are comparatively prolific and the daily egg production is high. Unlike *Chelonus*, *Microbracon* attacks a moving host, must paralyse it and then oviposit on it. The search for hosts and the act of oviposition apparently takes place in two distinct phases (Ullyett, 1945). The deposition of eggs is therefore a function which is more or less periodic in nature and batches of eggs are presumably ready for laying at certain intervals of time. In the

experiments, the female parasite would parasitize its hosts by first paralysing all living larvae in the environment and then returning to oviposit on them. This is probably the procedure adopted in the natural environment of the parasite since it normally inhabits the very restricted micro-environment of its usual hosts, the lepidopterous pests of stored products, and this was very largely reproduced in the small cages used in the experiments. It is therefore a relatively simple matter for the parasite to re-locate immobilized hosts and these can readily be examined for previous parasitism.

Microbracon deposits more than one egg per host, several progeny usually being able to mature on each host larva. The female therefore requires less hosts for the reception of her daily quota of eggs than does a female *Chelonus*. This is an obvious advantage both in the case of a restricted oviposition period and where there is a shortage of host individuals within the given area. It is also correlated with the relative abundance of hosts which may probably occur in nature in the two cases, eggs being usually more plentiful than larvae. In this respect, *Microbracon* is intermediate between *Chelonus* and *Cryptus*. On the other hand, *Microbracon* is apparently able to gauge the size of the host in relation to the number of progeny it can support to maturity and to adjust the number of eggs laid per host accordingly—a faculty which is very necessary in this type of parasitism in order to prevent the intervention of true superparasitism but which is not necessary in either *Chelonus* or *Cryptus* and which is not possessed by these two species to any marked degree.

In *Cryptus* populations, the females are characterized by a very low daily reproductive potential (2 eggs maturing per day) as well as by a comparatively low total potential (30 to 40 eggs). The daily requirements in the matter of hosts are therefore modest in comparison with the two other species. Because of this, the factor of host density is of less importance in determining the efficiency of the parasite in destroying the host and in the distribution of its progeny, except when hosts are abnormally scarce. Provided that sufficient hosts are available for the reception of the daily eggs, the females show a high percentage realization of the potentialities pertaining to the discriminative faculty. As with *Microbracon*, the experimental data show an apparent indication that searching for hosts and oviposition form two distinct phases in the reproductive life of the female.

Cryptus females are robust and active and the fact that their maximum requirements per day consist of only two host individuals renders it comparatively simple for them to complete the searching successfully in the time available, except under extremely adverse conditions of host density or with unfavourable environmental conditions. It is evident that *Cryptus* is a parasite which should be able to maintain itself at a relatively low host concentration per unit area, although this does not necessarily imply that its population will be large or will markedly increase under these conditions.

In analysing the experimental data given above, a number of significant factors appear which regulate the relationship between *Cryptus* and its host during the distribution of progeny by the former. These factors serve to modify the efficiency of the female and hence the extent of survival of the progeny and the consequent level of the parasite population during each ensuing generation. Briefly, these factors are:

(1) A psychological one which endows the female parasite with the ability to distinguish between hosts which are suitable for the development of her progeny and those which are unsuitable. Without this basic faculty, all the eggs produced by the parasite would be distributed at random and we should observe results which would accord with the laws of probability. As pointed

out by the present writer on a previous occasion (Ullyett, 1936), the exercise of the faculty implies a *recognition* of the host.

(2) A physiological factor which is determined by the rate at which the eggs of the parasite mature within the ovaries. Maturation of ova must produce a physiological urge to release those eggs within a given time and the frequency with which this urge appears will determine the number of hosts which must be found during a given period as well as the method of oviposition itself. The requirements of the parasite and its success during a fixed period are therefore relative to the rate of maturation of ova. In the case of *Cryptus* approximately two mature eggs are produced every 24 hours so that a total of only two hosts need be found during that time. Since the eggs are matured at comparatively long intervals, we find that searching and oviposition are apparently conducted in two operations. In contrast, the same two phases of activity are simultaneous with *Chelonus* and proceed almost continuously.

In *Cryptus*, the induction and inhibition of the act of attacking and paralysing host individuals is apparently regulated by the physiological stage attained by the female. Thus the production of a mature egg in the ovary and its passing into the oviduct will, according to this assumption, inhibit further search for hosts and initiate the deposition of the egg onto one which has already been prepared for its reception. On the other hand, the absence of an egg in the oviduct will mark the phase during which searching for new hosts takes place actively. Since the production of mature ova is a rhythmical process, it follows that the search for hosts alternates rhythmically with oviposition so that we should obtain results similar to those recorded in the experiments above.

It may be questioned whether such an explanation suffices to meet the situation present in the field. Unlike *Microbracon*, *Cryptus* works in a more open type of environment where unrestricted movement can take place and where the area is relatively large in comparison to the size of the parasite. Hosts once paralysed and left may be difficult to find again unless the parasite is guided thereto by some kind of "sign-post". Furthermore, the postulate that paralysis and oviposition take place in two distinct phases gives rise to the necessity for the parasite to ascertain whether a re-located host is parasitized or not. In other words, the female must not only find a host she has immobilized previously but must also find one which she has not yet used.

On the other hand, it is probable that individual parasites working in the field do so within a comparatively small area each day. The host population is normally concentrated in what are, essentially, population units which are situated around the base of the former larval feeding ground. There is thus a virtually closed environment of hosts and once the parasite has found one of these population units, it is unlikely that it will leave it until its immediate needs, at least, are satisfied. Hosts are therefore relatively easy to find and presumably almost as readily re-found. The postulate is therefore feasible but there are no data from the field to support it and it would be difficult to accumulate the necessary proof. The apparent occurrence of the phenomenon in the laboratory experiments may be an artifact induced by the artificial conditions and may have no relation to field conditions.

(3) A density-dependence factor is clearly shown by the results obtained by varying the ratio of hosts to parasites per unit area. The importance of this factor varies according to whether one or more parasite progeny can develop on each host individual, to the reproductive potential of the female parasite per unit of time and to the relative abundance of host material normally occurring in the environment (i.e., whether the host insect is usually present in large numbers or not in the field). From the inherent difference between two parasites

like *Cryptus* and *Chelonus* it is clear that the factor of the host/parasite ratio will be less important in the former than in the latter species.

(4) A psychological factor is evinced in the ability of the parasite to exert a greater effort in finding hosts when the act of searching the environment is made more difficult by increasing the total area which must be covered by the female in order to find a host individual. This faculty was demonstrated in the experiments described above.

(5) The factor of population pressure becomes evident when the density of the parasite population is increased within the given area while the host population is maintained at a constant but adequate level. This is reflected in a decrease in efficiency in the distribution of progeny by the individual parasites and by a proportional decrease in the capacity of the population *per individual* to destroy hosts. In this factor we have an interference factor mixed up with the effect of a reduced host/parasite ratio and these, together, produce the general effect attributable to population pressure. The relative importance of the two factors varies with the species concerned, i.e., with the habits of the species during the reproductive activities. In the case of *Cryptus*, the interference factor tends to become more and more important as the population of parasites increases, so that the host/parasite ratio assumes a relatively minor role. At lower population densities, however, the latter factor is the more important one.

The situation as it applies to *Cryptus* contrasts with the findings of Carpenter (1944) who, working with *Microbracon mellitor* Say, an ectoparasite of *Anthonomus grandis* Boh., found that increasing parasite density per unit area was followed by a decrease in the productivity of the individual female parasites. In this case the parasite lays one egg on each paralyzed host larva, a habit comparable with that of *Cryptus*. The decrease in egg production was thought to be due partly to competition among the parasites and partly to the deposition of fewer eggs as a result of the females spending a longer time in searching for unparasitized hosts.

The sum total of the factors impinging upon the organism during any given period of time serves to modify the operation of the basic faculty of discrimination possessed by the female parasite, so that the progeny of the latter are rarely distributed in such a manner that 100 percent efficiency is attained. Some progeny are always found in unsuitable hosts so that a proportion of the total progeny thus dispersed represents a wastage of eggs and a partial failure of the discriminative faculty. It is probable that an approximate efficiency of 80 percent represents the normal or more usual maximum attained under the most favourable conditions, but this figure will naturally vary according to the species of parasite concerned and the degree of development of the faculty.

This partial breakdown in the basic psychological factor results in superparasitism and gives the impression that the progeny are distributed at least partially at random. The experimental evidence so far accumulated, however, does not support any theory of random action on the part of the parasite but, on the contrary, points in the opposite direction. This is clearly shown in the frequency distributions in each of the species dealt with by the present writer. In each case the mode invariably and very definitely lies at the point indicating the best possible chances for the survival of the progeny, thus demonstrating convincingly the deliberate choice of suitable hosts by the parasite on the majority of occasions. This choice is not confined to those cases where the general environmental conditions are particularly favourable but extends to the less favourable ones, showing that the faculty is strongly developed and constitutes a powerful influence under all circumstances.

Work done by previous investigators on parasite behaviour also supports this evidence. There is, for example, the work of Salt (1932) and Walker (1937) on *Collyria calcitrator* Grav. in field samples, the laboratory work of Lloyd (1938) on *Ooencyrtus kuvanae* How. and on the parasites of the moth *Plutella maculipennis* Curt. (Lloyd, 1940), the observations of Parry Jones (1937) on *Telenomus ullyetti* Nixon and *Trichogramma lutea* Gir. in Southern Rhodesia and the study of Laing (1938) on *Trichogramma evanescens* Westw. In all of these cases there is overwhelming evidence of the presence of an extremely well-developed discriminative ability in the female parasite and of the non-random nature of the distribution of progeny.

We must therefore agree with the general conclusion of Thompson (1939) that it is a fallacy to attempt to equate the actions of the parasite with random action. While it is evident that aberrations occur in the actions of the ovipositing female which give rise to an imperfect distribution, this fact does not make the actions of the parasite random actions. A number of causes may severally or together contribute to this phenomenon, such as the physiological urge for the release of eggs becoming strong enough to overcome any inhibitions arising from an unfavourable situation. It is clear from the experimental evidence that some such powerful factor must operate to overcome the almost equally powerful instinct which prompts the female to strive for perfection in the distribution of her eggs. The physiological state of the organism during the reproductive period would appear to afford one of the more important basic explanations of this.

Summary

A study of the relationships between the parasite *Cryptus inornatus* Pratt and its host, *Loxostege sticticalis* L., was made in connection with the distribution of progeny by the former. The efficiency of the parasite in this respect is reflected in the number of viable progeny produced by each female under different environmental conditions and it is influenced by the relative sizes of the host and parasite populations within a given unit of area.

The efficiency of the parasite is governed by a number of factors, including the inherent psychological one induced by the possession of a strongly-developed discriminative faculty, the physiological one which is produced by the condition of the reproductive system at any given time, by the ratio between the host and parasite populations per unit area, by the ability of the parasite to exert greater efforts in the face of adverse conditions and by the effect of the pressure exerted by an increasing parasite population.

The fundamental part played by the discriminative faculty is emphasized by the persistence of the mode in the frequency distributions showing the number of hosts containing 1, 2, 3, ... n parasite progeny throughout the experimental series. This is consistently at the point at which the parasite progeny have the best possible chance of survival. This is true, not only of *Cryptus* but of the other two species studied previously (*Chelonus texanus* and *Microbracon hebetor*).

The behaviour of the parasite is very largely determined by its physiological function with regard to reproduction. *Cryptus* females mature a very limited number of eggs during a given period and hence require comparatively few hosts during that time. Therefore the absolute number of hosts per unit area is of less importance than in the case of more prolific parasites and the effect of adverse conditions of host density become apparent only at the lowest extreme. This is further apparent in the experiments dealing with increasing parasite density per unit area with a constant host population. Here, the effect of interference between ovipositing females is more important than is the effect of the increasingly adverse host/parasite ratio.

The evidence gleaned from the experiments with *Cryptus*, as well as from those with *Chelonus* and *Microbracon*, shows that the distribution of progeny among hosts is not fundamentally a random distribution but entirely the reverse. Any appearance of randomness in samples is not due to random action on the part of the parasite but to aberrations of instinct due to abnormal circumstances in the environment, such as an unfavourable host/parasite ratio per unit of area, combined with the physiological condition of the reproductive system at the time. Thus any attempt to equate parasite action with any theory based on the laws of chance is to adopt a fundamental assumption which is intrinsically unsound.

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Notes on the Species of Root Maggots Damaging Onions, Cabbage, and Radish at Ottawa in 1948[1]

By W. G. MATTHEWMAN, A. W. RATHWELL, and J. P. LACHAINE

In observations on the root maggots of garden crops in Canada made by A. R. Brooks in 1947 and later mimeographed (1) for officers of the Division of Entomology, Mr. Brooks indicated that there is frequently a complex of species in a field sample of larval Diptera; that the species and their numerical proportions are likely to vary both seasonally and geographically; and that not just one but 15 species of Diptera have been found in the roots of cabbage and as many as 14 in onions. He observed further that certain species of maggots appear directly responsible for the plant injury; others play a secondary role so that there is sometimes an involved ecological succession of species.

These findings cast doubt on the value of observations made in root maggot studies which lack a careful analysis of field populations. Since experiments on the biology and control of root maggots attacking vegetable crops have been conducted at Ottawa for many years, it seemed wise to appraise the situation in that locality. From root maggot material collected from onions and from cabbage in 1947[2], it was evident that species other than the onion maggot and the cabbage maggot attacked or occurred in these plants at Ottawa. However, there was little to indicate the proportions of the several species or to suggest which ones were responsible for the damage. In collections made in 1948[2], these points were considered, and also the time element, since it was thought that the size of the plant and the season of the year would have a bearing on the species present.

TABLE I.

SPECIES OF MAGGOTS COLLECTED FROM WILTED OR DEAD ONION PLANTS, CENTRAL EXPERIMENTAL FARM, OTTAWA, JUNE 4 — JULY 21, 1948

Date	Average height of onions	Species of maggot	Number collected				
			Larval instar			Pupae	Total maggots
			1st	2nd	3rd		
	inches						
June 4	2.0	*H. antiqua*	2	15	1	0	18
June 10	5.5	*H. antiqua*	17	111	75	0	203
		Platypalpus spp.	–	–	–	–	1
June 15	6.5	*H. antiqua*	0	12	170	10	192
June 21	10.0	*H. antiqua*	2	70	171	0	243
June 26	13.0	*H. antiqua*	0	6	286	27	319
		M. assimilis	0	3	0	0	3
June 30	16.0	*H. antiqua*	1	19	160	0	180
		Phorid species					10
July 3	17.0	*H. antiqua*	0	1	53	0	54
July 8	21.0	*H. antiqua*	0	4	52	0	56
		H. cilicrura	0	8	4	0	12
		Phorid species					3
July 14	23.0	*H. antiqua*	0	41	125	0	166
		H. cilicrura	0	4	3	0	7
		P. strigatus					5
		Phorid species					1
July 21	25.0	*H. antiqua*	0	0	20	0	20
							1493

[1]Contribution No. 2651, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.

[2]All identifications in this paper were made by A. R. Brooks, Dominion Entomological Laboratory, Saskatoon, Saskatchewan.

TABLE II.*

PROPORTIONS OF SPECIES OF MAGGOTS COLLECTED FROM WILTED OR DEAD ONION PLANTS, CENTRAL EXPERIMENTAL FARM, OTTAWA, JUNE 4 — JULY 21, 1948.

Species of maggot	Number collected					Percentage of total
	Larval instar			Pupae	Total	
	1st	2nd	3rd			
1. *Hylemya antiqua*	22	279	1113	37	1451	97.1
2. *Hylemya cilicrura*	0	12	7	0	19	1.3
3. Phorid species	—	—	—	—	14	.9
4. *Paragopsis strigatus*	—	—	—	—	5	.3
5. *Muscina assimilis*	0	3	0	0	3	.2
6. *Platypalpus* spp.	—	—	—	—	1	.1
			Totals.....		1493	99.9

Procedure and Results

Onions

In 1948, 45 plots composed of 9 varieties of onions served as a source of maggot supply in the early part of the season; for the late-season collections, 18 rows of onions 15 feet in length were seeded in a nearby location. Table I shows that maggot collections were made at weekly intervals from the time of the first attack, when the plants were only 2 inches in height, until the plants were 2 feet in height and wilting had ceased. Unfortunately, no results were secured on the 8 later records taken between July 27 and September 7, after wilting had ended; for these collections were lost in transit to Saskatoon, where they had been sent for identification.

However, the data in Tables I and II are complete in themselves and are highly significant. All the larval Diptera indicated in Tables I and II were collected from *wilted or dying onions*, showing that these maggots were responsible for the death of the plants or were associated with maggots causing the injury. Table II shows that 97 per cent of the maggots were the onion maggot, *Hylemya antiqua* (Meig.); 1.3 per cent were the seed corn maggot, *Hylemya cilicrura* (Rond.)[3]; .9 per cent were saprophytic Phoridae; .3 per cent were the onion bulb fly, *Paragopsis strigatus* (Fall.)[4]; .2 per cent were *Muscina assimilis* (Fall.); and .1 per cent were predaceous *Platypalpus*. From one season's data, therefore, the species responsible for the wilting and death of the onion plants at Ottawa in 1948 appears to be overwhelmingly the onion maggot.

Of 40 maggots collected from onion bulbs in storage on October 2, all were the onion bulb fly, *Paragopsis strigatus*. This indicates that the latter species may be responsible for a large part of the late-season infestation of the bulbs. The earliest collection of this species was made on July 14 (Table I), suggesting that it may not attack the young plants.

Cabbage

To make maggot collections from cabbage, 300 Golden Acre transplants were set out at City View on May 18 in 22 rows of 14 plants each. The cabbages

[3]*H. cana* (Macq.) is an older name for this species according to several European authorities. However, it has been thought preferable to retain in this paper the name familiar to American economic workers.

[4]The generic name *Eumerus* has been used for this species for many years.

were pulled and dissected at weekly intervals on 8 occasions between June 8 and July 26, the supply of plants being exhausted on the latter date. In the final three examinations, none of the plants was found to be infested. These data are shown in Tables III and IV.

The results with the cabbages were not so significant as with the onions since there were fewer plants, and also because the infestation of maggots on the cabbages was unusually light. There was practically no mortality of cabbages caused by maggots at Ottawa in 1948. By actual count very few eggs were laid, and, in addition, growth conditions for early cabbage were excellent. Of the 277 plants dissected at City View, only two wilted or showed obvious symptoms of maggot infestation in the field.

TABLE III.

SPECIES OF MAGGOTS COLLECTED FROM CABBAGE PLANTS, CITY VIEW, ONTARIO, JUNE 4 — JULY 26, 1948

Date	Cabbage Plants			Species of maggot	Number collected				
					Larval instar				
	Number dissected	Number infested	Average height, inches		1st	2nd	3rd	Pupae	Total
June 4	1*	1	4.0	*H. trichodactyla*	0	1	2	0	3
June 8	26	5	4.8	*H. brassicae*	0	5	6	0	11
June 15	34	17	6.3	*H. brassicae*	0	7	32	0	39
				H. cilicrura	0	0	1	0	1
				Platypalpus spp.					1
June 23	30	8	8.5	*H. brassicae*	0	1	17	4	22
				H. cilicrura	0	0	1	0	1
June 29	29	10	10.8	*H. brassicae*	0	0	21	1	22
July 5	47	9	12.6	*H. brassicae*	0	0	18	0	18
				H. cilicrura	0	0	0	1	1
July 12	43	0	14.8	—	0	0	0	0	0
July 19	40	0	14.8	—	0	0	0	0	0
July 26	27	0	14.2	—	0	0	0	0	0
	277	50							119

*The plant showed symptoms of maggot injury in the field which were not quite typical of cabbage maggot injury. Only one other of the 277 plants appeared obviously infested in the field.

TABLE IV.

PROPORTIONS OF THE SPECIES OF MAGGOTS COLLECTED FROM CABBAGE PLANTS, CITY VIEW, ONTARIO, JUNE 4 — JULY 26, 1948.

Species of maggot	Number Collected					Percentage of Total
	Larval instar			Pupae	Total	
	1st	2nd	3rd			
Hylemya brassicae	0	13	94	5	112	94.1
Hylemya cilicrura	0	0	2	1	3	2.9
Hylemya trichodactyla	0	1	2	0	3	2.2
Platypalpus spp.					1	.8
					119	100.0

According to Mr. Brooks' determinations of 137 maggots collected from the cabbage, 94 per cent were the cabbage maggot, *Hylemya brassicae* (Bouché); 3 per cent were the seed corn maggot, *Hylemya cilicrura* (Rond.); 2 per cent were *Hylemya trichodactyla* (Rond.); and .8 per cent (1 larva) were a predacious *Platypalpus*.

Radish

A test on the relation between the planting dates of radish and the degree of maggot injury was conducted at City View in 1948, and the bed was used also to supply infested radishes for maggot identification. There were 32 rows 10 feet long in the bed and there were 8 weekly plantings, 4 plots being sown on each date. The radishes were pulled and dissected on 7 occasions between June 9 and August 2 for the maggot collections.

As in the cabbage plots, the maggot infestation in the radish plots was light in 1948. Dissecting the radishes and searching for the maggots proved to be a slow process, and identifications were secured on only 98 maggots. The sixth and seventh collections on July 26 and August 2 were lost in transit to Mr. Brooks.

These data are summarized in Tables V and VI, which show that 92 per cent of the maggots were *Hylemya brassicae* (Bouché), 5 per cent were *Hylemya*

TABLE V.

SPECIES OF MAGGOTS COLLECTED FROM RADISH, CITY VIEW, ONTARIO, JUNE 9 — JULY 19, 1948

Date of radish seeding	Date of record	Species of maggot	Number Collected				
			Larval instar			Pupae	Total
			1st	2nd	3rd		
May 11	June 9	*H. brassicae*	1	4	0	0	5
May 11	June 15	*H. brassicae*	1	8	27	0	36
		H. trichodactyla	0	2	1	0	3
May 31	July 5	*H. brassicae*	0	5	27	0	32
		H. cilicrura	0	0	5	0	5
June 8	July 12	*H. brassicae*	0	1	2	0	3
June 14	July 19	*H. brassicae*	0	2	12	0	14
							98

TABLE VI.

PROPORTIONS OF THE SPECIES OF MAGGOTS COLLECTED FROM RADISH, CITY VIEW, ONTARIO, JUNE 9 — JULY 19, 1948

Species of maggot	Number Collected					Percentage of total
	Larval instar			Pupae	Total	
	1st	2nd	3rd			
Hylemya brassicae	2	20	68	0	90	91.8
Hylemya cilicrura	0	0	5	0	5	5.1
Hylemya trichodactyla	0	2	1	0	3	3.1
					98	100.0

cilicrura (Rond.), and 3 per cent were *Hylemya trichodactyla* (Rond.). Therefore, the proportions of species were much the same for cabbage and radish.

Apparently *Hylemya brassicae* is the species which caused most of the damage to radishes at Ottawa in 1948, though there is a suggestion that significant injury might occur from infestations of *Hylemya cilicrura* in a season which particularly favoured that species.

Summary

From one season's collections it appears that several species of root maggots may be found in onions, cabbages, and radishes at Ottawa, but in 1948 the species causing by far the greater part of the *spring and early summer damage* in onions was the onion maggot; and in cabbages and radishes, the cabbage maggot.

Reference

1. Brooks, A. R. The identification of the commoner root maggots of garden crops in Canada. Canada, Dept. Agr., Div. of Ent., mimeographed pamphlet. 1949.

Notes on Some Odonata from the Kenora and Rainy River Districts, Ontario

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In the writer's list of the Odonata of Ontario* fifty species were recorded from the Kenora District of Ontario and only one from the Rainy River District. Thirty-five are reported from the vast northern part of the District known as the "Patricia Portion" and twenty-three from the southern part. The records from the Patricia portion are all from three widely separated localities but probably give a fair general picture of the odonate fauna of these northern latitudes. The records from the southern part of the District, on the other hand, are almost entirely from one locality, Minaki (approx. 50° N. Lat., 9° W. Long.) and are quite inadequate even for that one locality, some of the commonest regional species not being included.

During the summer of 1947 the Royal Ontario Museum of Zoology sent an expedition to the southern part of the Kenora District, collections having been made at Sioux Lookout (50° N. Lat., 92° W. Long.) and Malachi (50° N. Lat., 95° W. Long.). Mr. W. Y. Watson had charge of all insect groups and his collection of Odonata, numbering 209 specimens, fills some of the gaps in our knowledge of the distribution of this order in western Ontario.

In July, 1949, a few days were spent by the writer at Fort Frances, Rainy River District, and a little collecting of dragonflies was done in the vicinity of this town and in a few localities along route No. 70, in both the Rainy River and Kenora Districts, while we were travelling to Kenora and westward. In the vicinity of Fort Frances most of our collecting was done on the estate of Mr. J. Matthews, about 14 miles west of the town. This estate covers an area of about 9000 acres and includes an extensive tract of marsh and swamp, on which Mr. Matthews has constructed a number of large artificial ponds with high retaining walls for the encouragement of breeding ducks and other waterfowl. There is also a beaver pond and numerous smaller ponds and pools in the surrounding marsh and swamp.

On our return trip in late August we followed the same route through this particular section, and a few additional specimens were collected at Sioux Narrows on the Lake of the Woods, Kenora District.

*Trans. R. Can. Inst., Sept. 1941, 23 (part 2): 201-265.

One other collection is recorded here, that was made in 1948 on Cape Henrietta Maria, Patricia portion of the Kenora District, and the most northeasterly point in Ontario. This collection was also made by Mr. W. Y. Watson, who was a member of another expedition organized by the Royal Ontario Museum of Zoology. The terrain at the Cape is arctic tundra to a distance of about 15 to 25 miles from the coast of Hudson Bay, yet dragonflies of a few species were flying in large numbers. Although many of them were juvenile there was no evidence that they had emerged locally, all possible types of breeding place, including several small streams, having been searched for nymphs and exuviae with negative results.

In the following lists the records from the Rainy River District and the southern part of the Kenora District are combined, since they represent essentially the same faunistic area within the Canadian Zone, while those from Cape Henrietta Maria comprise a second list, since this locality belongs to the Arctic, although the dragonflies may be more properly considered as Hudsonian.

Southern Kenora and Rainy River Districts

Records from the Kenora District are indicated by (K), those from the Rainy River District by (RR).

Zygoptera

Lestidae

Lestes congener Hagen. Gravel pit 7 miles north of Sioux Narrows, Lake of the Woods, July 18, 1 ♀ teneral (K). This is an early record for this species and the first one for western Ontario, although it is regional across the Continent.

Lestes unguiculatus Hagen. Malachi, July 31, 1 ♂ (K); ponds in Matthews' estate, July 15, 16; 3 ♂ (RR).

Lestes dryas Kirby. Gravel pit 7 miles north of Sioux Narrows, July 18, 1 ♀ (K).

Lestes disjunctus Selys. Malachi, July 24, 1 ♂, teneral (K); Matthews' estate, July 15, 1 ♂, mature, a few immatures seen on July 15 and 16, the season having just begun; One-sided Lake, July 17, myriads of juveniles, some just emerged, a few nearly mature, on the shore vegetation of the lake, a few penetrating the woods for about a hundred yards (RR).

Lestes forcipatus Rambur. Marshy ponds in Matthews' estate, July 16, 3 ♂; One-sided Lake, July 17, 1 ♂ (RR). These specimens are all mature. Emergence begins long before that of *L. disjunctus*.

Lestes rectangularis Say. Malachi, July 22, 1 ♂ (K); Fort Frances, July 14, 1 ♂ in low wood near stream; pool in river valley near Fort Frances, July 15, 5 or 6 seen, mostly males (RR).

Lestes inequalis Walsh. Open marsh bordering Lake of the Woods, 5 miles north of Sioux Narrows, July 18, 1 ♀. This is the first Canadian record for this species west of Georgian Bay and the most northerly record in its range.

Coenagrionidae.

Argia moesta Hagen. Sioux Narrows, August 9, 1 ♂, heavily pruinose, from the rocky shore of the Lake of the Woods; a few others seen. This is the first record of the occurrence of this species in Canada west of Lake Huron and Lake Timagami. Its apparent scarcity was probably due to the prevailing dull weather.

Enallagma boreale Selys. Sioux Lookout, June 22, 1 ♀; July 2, 4 ♂; July 5 and 9, 2 ♀ (K). The season of adult life was apparently over on our arrival at Fort Frances, for it is generally distributed and common at this latitude.

Enallagma vernale Gloyd. Sioux Lookout, June 23 and 30, 2 ♂, July 5 and 9, 6 ♂; Malachi, July 15 and 16, 2 ♂ (K). This species, which has been confused

with *E. cyathigerum*, Charp., has hitherto been known in Ontario only from the southern part of the Province.

Enallagma hageni Walsh. Sioux Lookout, July 5 and 9, 2 ♀ (K); roadside pond near Matthews' estate, July 15, abundant; Matthews' estate, July 16, plentiful around the duck ponds and all smaller ponds; Pine Lake, July 17, abundant; One-sided Lake, very abundant, only one pair noted (RR); Sioux Narrows, July 17, abundant (K).

Enallagma ebrium Hagen. Matthews' estate, July 16, 2 ♂, taken from one of the partly shaded ponds, one of them with an unusually large amount of black on the abdomen. This species was unexpectedly scarce (RR).

Enallagma carunculatum Morse. Malachi, July 13, 2 ♂, one just emerged; July 18 and 25, 3 ♂, 5 ♀; Sioux Narrows, August 8 and 9, juvenile females were scattered in the woods within fifty yards of the shore; one pair in cop. taken on the lake shore and another seen (K).

Enallagma civile Hagen. Matthews' estate, July 16, 1 ♂ taken at a shallow pond part of the overflow from one of the large duck ponds. Search was made for other specimens but without success (RR).

Coenagrion resolutum Hagen. Sioux Lookout, July 4 and 5, 1 ♂, 1 ♀ (K); near Fort Frances, July 15, flying here and there over a small somewhat shaded pond in river valley, 1 ♂ and a pair in cop. taken; Matthews' estate, July 16, single males not uncommon in the shadier parts of the swamp and small ponds, (RR).

Coenagrion angulatum Walk. Sioux Lookout, July 1 1 ♂, 1 ♀. Previously known in Ontario only from Minaki.

Ischnura verticalis Say. Sioux Lookout, July 2, 1 ♂ 1 ♀, both juvenile; July 9, 2 orange ♀ s (K); Pine Lake, July 17, abundant on a cleared slope near the lake, orange females and males, only one or two pruinose females. (RR).

Since nearly all the specimens collected or observed were young, it would seem that this species emerges later here than in southern Ontario, where the main peak of emergence is in early June, with a lower peak in July or August, the late summer individuals averaging smaller than those of the spring brood. The specimens recorded above are uniformly larger than the average from southern Ontario, even of the spring brood. Typical measurements are as follows: abd. ♂ 24.5, ♀ 24, hind wing ♂ 16, ♀ 18. Measurements of average specimens from southern Ontario, taken in June are: abd. ♂ ♀ 21, h.w. ♂ 13, ♀ 15. Specimens taken in July and August are still smaller.

This species, which is ubiquitous in southern Ontario is apparently quite local in the Kenora and Rainy River Districts.

Nehalennia irene Hagen. Sioux Lookout, July 3-8, 2 ♂, 2 ♀ (K); Malachi, July 14, 23, 24, 3 ♀ (K); Matthews' estate, July 15 and 16, abundant everywhere in the marsh and about every pond, except the large open duck ponds, a great many pairs noted; Pine Lake, July 17, a few seen, doubtless common (RR); 5 mls. north of Sioux Narrows, July 18, abundant in marsh bordering Lake of the Woods (K).

Anisoptera

Gomphidae

Hagenius brevistylus Selys. Malachi, July 22, 1 ♀. Sioux Narrows, July 17, one seen in the hotel clearing, close to the Lake of the Woods (K).

Gomphus lividus Selys. Sioux Lookout, July 4, 3 ♂, 1 ♀; July 8, 2 ♂, 1 ♀ (K). First record of this species from western Ontario.

Gomphus exilis Selys. Sioux Lookout, July 8 and 9, 1 ♂, 1 ♀; July 15, 2 ♂, 1 ♀; Malachi, July 15-31, 10 ♂, 7 ♀ (K).

Dromogomphus spinosus Selys. Malachi, July 24, 31, 1 ♂, 1 ♀ (K). First record from western Ontario.

Aeshnidae

Basiaeschna janata Say. Sioux Lookout, July 2, 3 ♂, 1 ♀; July 4, 1 ♂; Sioux Narrows, Aug. 9, 2 exuviae (K). The date of the last record has no significance, as it is long after the time of emergence or of flight.

Aeshna eremita Scudd. Near Fort Frances, small pond in river valley, July 15, one seen. This individual was too large for any other species and was plainly seen. It visited the pool for a few minutes. Matthews' estate, July 16, one or two were noted, flying along the wall of a large duck pond, easily recognized as this species (RR); 5 mls. north of Sioux Narrows, July 18, a male flew along the narrow channel between the rocky shore and the floating bog and was closely observed. A wing of this species was found at Sioux Narrows on July 17.

Aeshna interrupta lineata Walk. Malachi, July 19-31, 4 ♂, 2 ♀, Aug. 3, 1 ♂ (K). In this series there is no suggestion of variation towards the eastern subspecies *A. i. interrupta* Walk., such as was found in the material from the Favourable Lake region. Malachi is only 14 miles from the Manitoba boundary line.

Aeshna canadensis Walk. Malachi, July 14-31, 13 ♂, 14 ♀ (K). The majority of these were taken on July 28.

Aeshna sitchensis Hagen. Malachi, July 18-23, 1 ♂, 2 ♀ (K).

Corduliidae

Didymops transversa Say. Sioux Lookout, July 3, 1 ♀ juv., July 4, 1 ♂ juv., July 8, 1 ♂ (K).

Macromia illinoiensis Walsh. Sioux Lookout, July 10, 1 ♂, 1 ♀, both juv., the female with amber-coloured wings; Malachi, July 25, 1 ♂ (K). These specimens are rather large and robust.

Tetragoneuria spinigera Selys. Sioux Lookout, July 2, 1 ♂, 1 ♀, both juv. July 5 and 9, 1 ♂, 1 ♀; Malachi, July 14, 1 ♂, 1 ♀ (K); Pine Lake, 15 mls. north of Nestor Falls, July 17, 1 ♂ (RR). The specimens are all of large size, like those from the north shore of Lake Superior. Measurements of typical specimens are as follows: abd. (excl. apps.) ♂ 33, ♀ 33.5; hind wing ♂ ♀ 34.5.

Tetragoneuria canis McLachlan. Sioux Lookout, July 2, 1 ♂, 1 ♀; July 5, 3 ♂; July 9, 6 ♂ (K). The specimens in this series are of the usual size. Typical measurements are: abd. (excl. apps.) ♂ 30, ♀ 36.5; hind wing, ♂ 31, ♀ 32. The wings of the single female show the dark yellow colour, with clearer apices, which in this species is an indication of maturity, instead of juvenility as it usually is in the Corduliidae.

Cordulia shurtleffi Scudd. Sioux Lookout, June 28, 1 ♂; July 2-9, 2 ♂, 5 ♀ (K).

Dorocordulia libera Selys. Sioux Lookout, July 8, 1 ♂ (K).

Libellulidae

Libellula quadrimaculata L. Sioux Lookout, June 30, 1 ♂; July 1 and 3, 2 ♀; Malachi, July 12 and 13, 1 ♂, 1 ♀ (K); Matthews' estate, July 16, many flying over shallow ponds bordering the walls of the large duck pond, also at the beaver pond, examples all old (RR); small pools in quarry, 7 mls. north of Sioux Narrows, July 18, common (K).

Libellula pulchella Drury. Matthews' estate, several males flying over the water-filled ditches on both sides of the road and over the shallow ponds bordering one of the large duck ponds. (RR).

Libellula julia Uhler. Malachi, July 22, 1 ♀; 5 mls. north of Sioux Narrows, July 18, 1 mature ♂ seen (K).

Sympetrum internum Montg. Malachi, July 31, 1 ♂, 1 ♀ (K); Fort Frances, Aug. 10, common in an open field (RR).

The male from Malachi has flavescent wings, a feature that is unusual in the male but common in the female of this species in the western half of its range. In central and southern Ontario and eastward, *S. internum* lacks the yellowish staining of the wings in both sexes and the venation is fuscous instead of reddish. This eastern form appears in June several weeks earlier than *S. obtrusum*, while the western form emerges late in July and in August, when *S. obtrusum* is mature. This is doubtless why we did not find *S. internum* in the vicinity of Fort Frances on our westbound journey (July 15-18) but found it common there on our return trip in August. It also explains why there are only two specimens in the collection made by Mr. Watson, no Odonata having been collected after August 3rd.

As Dr. Montgomery has assembled a large quantity of material representative of the entire range of *S. internum* and has signified his intention of making a critical study of this material we shall make no further comments on the taxonomic status of the two forms mentioned.

Sympetrum obtrusum Hagen. Malachi, July 13-31, 18 ♂, 12 ♀ (K); Fort Frances, July 15, tenerals just emerged from a small roadside pond west of the town; small pond in river valley, a few males hovering and hawking over the water; Matthews' estate and neighbouring fields, July 15 and 16, multitudes of juveniles and a few mature individuals; One-sided Lake, July 17, tenerals of both sexes abundant (RR); Sioux Narrows, July 18, juveniles not infrequent (K).

Sympetrum semicinctum Say. Five miles north of Sioux Narrows, July 18, two were seen in a clearing by the roadside but were not captured, no net being available at the moment (K). They appeared to be quite typical of the eastern subspecies *S. s. semicinctum*. This species was hitherto unknown in Western Ontario.

Sympetrum danae Sulz. Matthews' estate and vicinity, July 15 and 16, 2 ♀ juv.; Fort Frances, Aug. 10, common (RR); 7 mls. north of Sioux Narrows, 1 ♂ juv. at a small quarry pool(K). The adult season was just beginning on our westward journey and was in full swing during our return trip.

Leucorrhinia hudsonica Selys. Sioux Lookout, July 5, 2 ♂. A female *Leucorrhinia*, apparently of this species, was seen ovipositing about five miles north of Sioux Narrows, on July 18. She flew near the water, which she tapped irregularly, not remaining over one spot.

In Mr. Watson's collection there are also two males taken on June 18, at Nakina, Ont., at the beginning of the expedition. This locality is in the Thunder Bay District and is therefore outside the territory considered in this report. The paucity of specimens in July is not surprising at the relatively southern latitudes where the main collections are made.

Leucorrhinia glacialis Hagen. Malachi, July 15, 1 ♀, July 16, 1 ♂ (K).

Leucorrhinia proxima Calvert. Sioux Lookout, July 5, 1 ♂, 2 ♀; Malachi, July 16, 1 ♀ (K); Matthews' estate, July 16, 1 ♂ taken and several others seen, all old. They flew about one of the larger overflow ponds in the marsh. Five miles north of Sioux Narrows, July 18, fairly common in the marsh and on the rocks along the shore of the Lake of the Woods. Only 1 ♂, 2 ♀ were taken, all old, the season of flight being evidently nearly over. The size is rather large all through this district, as indicated by the following measurements of specimens from Sioux Lookout and Malachi: Length of abd. (mm) ♂ 24.0-24.5, ♀ 22.0-25.5; hind wing, ♂ 26.5, ♀ 26.5-27.5.

Leucorrhinia intacta Hagen. Sioux Lookout, June 28, 1 ♀; July 7 and 9, 3 ♀ (K); Matthews' estate, not uncommon over all the pools but only 1 ♂ was collected; Pine Lake, July 17, one seen on the ground (RR).

All four females from Sioux Lookout are larger than is usual in southern Ontario and have wings more or less pigmented, a peculiarity associated with late emergence in this species. In the June specimen the pigmentation is dark yellow, darkest about the basal fourth and along the costal margins, becoming very diffuse beyond the nodus. In the July specimens, which are more juvenile, the wings are deep brown from the base to a varying distance beyond the nodus, the apices being hyaline. The measurements of these four females are as follows: —length of abdomen (mm.) 23-26, hind wing 27.5-28.0. Measurements of females from southern Ontario are: abdomen 19-21, hind wing 24-25.

Appendix to the Above List

Agrion aequabile Say. In the collection of Wm. Brodie now in the Royal Ontario Museum of Zoology there is a male of this species, labelled "Rainy River District, line of G.T.P. 1907. H. Cook". ("G.T.P." refers to Grand Trunk Pacific, now the Canadian National Railway).

The specimen is of the form known as *A. aequabile hudsonicum* Selys, but we are very doubtful of the validity of this form as a subspecies.

Cape Henrietta Maria, Patricia portion of the Kenora District

Coenagrion interrogatum Hagen. July 9, 2 ♀, washed up on the sea beach.

Aeshna coerulea septentrionalis Burm. July 8 and 11, 2 ♀.

Aeshna sitchensis Hagen. July 3-22, 20 ♂, 24 ♀. Of these 44 specimens 17 were taken on July 10 and 19 on July 11. Four of the specimens were drowned and washed up on the sea beach.

Somatochlora franklini Selys. July 9, 2 ♂, 2 ♀ (all but 1 ♀ drowned); July 10, 26 ♂, 22 ♀, none drowned. All of the specimens are somewhat juvenile, ten of the females having more or less smoky wings.

Somatochlora whitehousei Walk. July 10, 2 ♂, 5 ♀, July 11, 1 ♂.

Somatochlora septentrionalis Hagen. July 10, 1 ♂.

Somatochlora albicincta Burm. July 10, 1 ♂, 2 ♀.

Leucorrhinia hudsonica Selys. July 8, 2 ♂, 1 ♀, all drowned; July 11, 7 ♂, 5 ♀; July 12, 1 ♂, 2 ♀; July 13, 1 ♂, 1 ♀. The specimens are of small to average size.

Leucorrhinia patricia Walk. July 11 and 12, 2 ♀.

Leucorrhinia proxima Calvert. July 11, 1 ♀, rather small.

Larval and Pupal Development of *Dermestes maculatus* Degeer Under Controlled Conditions of Temperature and Relative Humidity

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Introduction

The hide beetle, *Dermestes maculatus* Degeer, is a cosmopolitan insect which each year causes considerable losses to stored products throughout the world. The economic importance of this species is due especially to the habit which the mature larvae have of boring into many commodities in order to pupate. However, the larvae and adults also feed on and thus damage a wide variety of substances with a high protein content (4), e.g., bones, carcasses, skins and hides of all kinds, etc.

The adult male measures from 5.5 to 10 mm. The cuticle is shining and reddish brown to black. The dorsal surface is densely clothed with recumbent, yellowish to grayish hairs and also with a few black hairs. The ventral surface is covered for the most part with dense white hairs. The fourth abdominal sternite presents a large, round, shallow depression, about one fourth as long as the sternite, from which arises a long erect brush of dense, golden hairs. The antennae are short and club shaped.

The adult female is externally similar to the male but lacks a pit and brush of hairs on the fourth abdominal sternite.[2]

Hinton (2) gives a very comprehensive review of the research effected on this insect. But it was noted that although the effect of temperature has been studied quite often, nearly all the workers have disregarded the effect of humidity on the development of the immature stages. Faced with this fact, it was deemed interesting and useful to study the combined effects of various combinations of temperature and relative humidity on the development of the egg,[2] larval and pupal stages of the hide beetle.

Experimental Methods

The experiments were conducted in four constant temperature chambers kept at 25, 28, 31 and 34°C. respectively. The relative humidity was kept constant by using the method described by Buxton and Mellanby (1) in 1934. This method employs various concentrations of sulfuric acid and distilled water. Relative humidities of 0, 20, 50, 70 and 100% were used at each of the four temperatures. The beetles under experiment were fed Purina chow (checkers) which had previously been dehydrated. The insects used in the experiments were reared from eggs laid at 28°C. by females abundantly supplied with food and water.

The larvae were placed under experimental conditions within 1 hour after their emergence. Each larva was deposited in a separate vial containing food. Eighteen larvae were used at each combination of temperature and relative humidity.

Approximately forty pupae were submitted to each combination of temperature and relative humidity. They were placed under experimental conditions within 1 hour after pupation.

[1]This paper is an abstract of an M.Sc. thesis of which Prof. Bellemare was director of research.
[2]The effect of these combined factors on the development of the egg stage is being studied at the present time.

Results

The Larva:

Complete larval development occurred only at 70 and 100% r.h. Although most of the insects submitted to the lower humidities (0, 20 and 50%) moulted, their development was arrested during the second larval stage. At 70% r.h. and 25°C., an average of 8 moults was registered, while at the other temperatures and the same relative humidity an average of 7 moults was noted (see Table 1). At this r.h., a few larvae moulted 11 and 12 times. At 100% r.h. and at each of the four temperatures, there was an average of 5 moults (see Table 1). These

TABLE 1.
Number of moults and duration (days) of larval stages of *Dermestes maculatus* Degeer.

R.H.		25	28	31	34	°C.
70%	No. of moults	8	7	7	7	
	Mean duration of larval st.	5.8	4.8	4.3	4.2	
100%	No. of moults	5	5	5	5	
	Mean duration of larval st.	3.9	3.6	2.4	2.4	

results do not agree with those obtained by Kreyenberg (3). This author would have the temperature alone capable of modifying the number of moults, the humidity regulating the length of the larval stages. It is evident from the given results (see Table 1) that while the humidity does regulate the length of the larval stages, it also modifies the number of moults; for, if the results obtained at 70% r.h. are compared with those obtained at 100% r.h., a fall in the number of moults is noted at the latter r.h. A temperature increase at a given r.h. appears to shorten the duration of each larval period.

The Pupa:

The results obtained indicate that the relative humidity of the environment has no influence on the duration of the pupal period, while a rise in temperature from 25 to 34°C. greatly shortens this period (see Table 2).

Summary

Experiments were conducted in view of studying the combined effect of constant temperatures and humidities on the development of the larval and pupal

TABLE 2.
Duration of pupal period of *Dermestes muculatus* Degeer.

R.H.	25	28	31	34	°C.
0%	8.6	7.0	6.0	5.0	
20	8.6	6.8	5.7	5.0	
50	8.5	7.0	5.8	5.0	
70	8.5	7.0	5.7	5.0	
100	8.5	7.0	6.0	5.0	

stages of the hide beetle, *Dermestes maculatus* Degeer. Different combinations of temperature and relative humidity were used, viz., 25, 28, 31 and 34°C. and 0, 20, 50, 70 and 100% r.h.

Th results obtained show that these combined factors have a marked influence on the total duration of the larval period, but that only the temperature affects the duration of the pupal period. The results may be summarized as follows: 1) a rise in temperature and relative humidity considerably shortens the total duration of the larval period; 2) the number of moults is decreased by an increase of the relative humidity from 70 to 100%; 3) the duration of the pupal period is shortened by raising the temperature, but it is not affected by the environmental humidity.

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THE RUNGE PRESS LIMITED, OTTAWA
Mailed: Thursday, April 27th, 1950